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THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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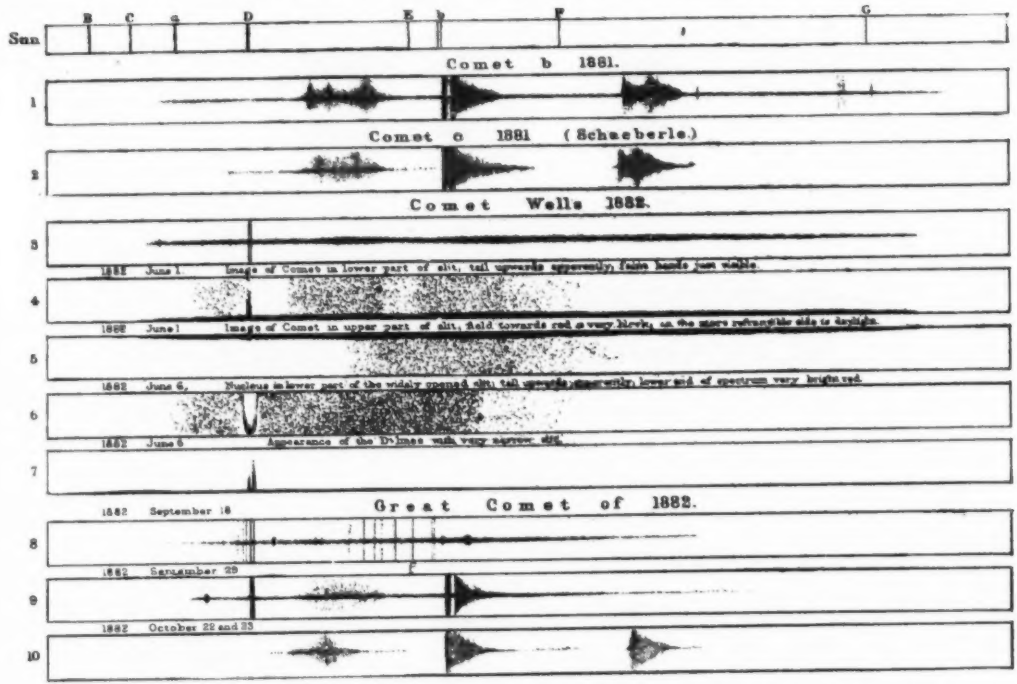
PLATE IX

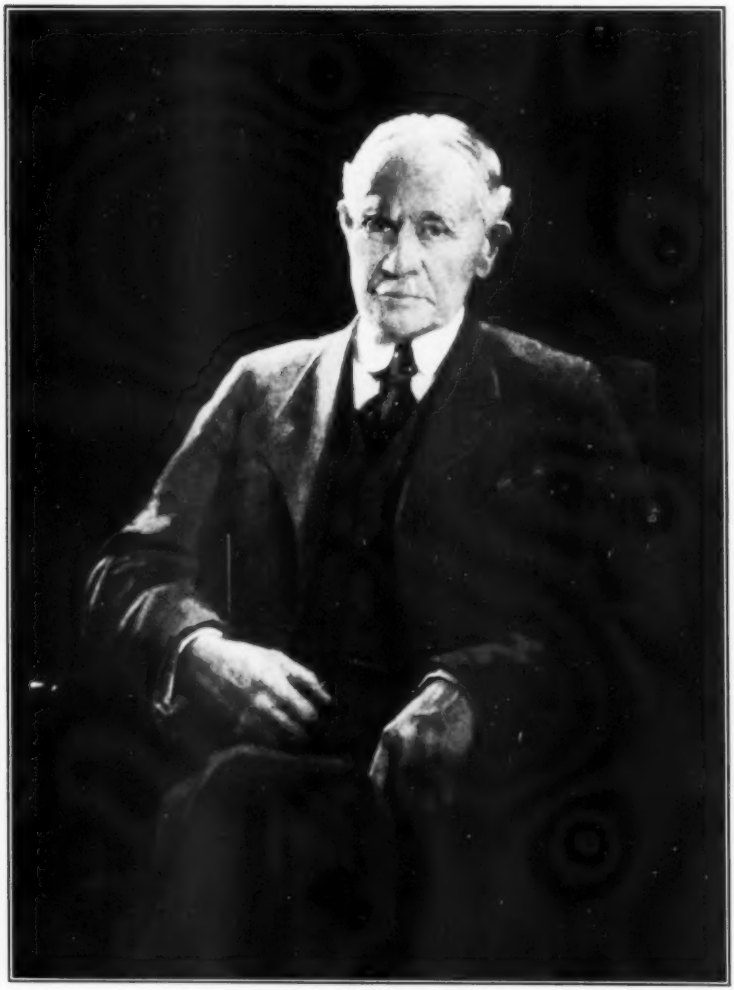
To accompany "A Synopsis of Cometary Spectra" by Frank S. Hogg


Sun
B
C
D
E
F
G
Comet b 1881.
1
Comet c 1881 (Schaeberle.)
2
Comet Wells 1882.
3
1882 June 1 Image of Comet in lower part of slit; tail upwards apparently, faint bands just visible.
4
1882 June 1 Image of Comet in upper part of slit; field towards red a very little, on the more refrangible side is daylight.
5
1882 June 6, Nucleus in lower part of the widely opened slit; tail upwards, apparently, lower end of spectrum very bright red.
6
1882 June 6 Appearance of the D lines with very narrow slit.
7
1882 September 16
Great Comet of 1882.
8
1882 September 29
9
1882 October 22 and 23
10

The above plate, reproduced from "Copernicus," Vol. II, 1882, summarizes the comet observations of Copeland and Lohse. The metallic lines of Table II are shown in Spectrum 8, above.

Journal of the Royal Astronomical Society of Canada, 1929.

PLATE X



SIR FREDERIC STUPART

Retiring Director of the Meteorological Service of Canada—(From the portrait by E. Wyly Grier, R.C.A.)

THE JOURNAL
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PRESENTATION OF THE PORTRAIT OF SIR FREDERIC STUPART TO THE METEOROLOGICAL OFFICE ON JANUARY 7th, 1929

The high esteem in which Sir Frederic Stupart is held was evidenced by the presence of the Lieutenant-Governor and Mrs. Ross and a large number of influential friends at the presentation of his portrait on the evening of January 7th in the Meteorological Office, Toronto.

A rumour was current some months ago that Sir Frederic Stupart intended shortly to sever his connection with the Meteorological Service, and it was felt that his retirement should not take place without some mark of appreciation. To consider the matter a committee was formed consisting of Alex. Johnston, Esq., Deputy Minister of Marine, Ottawa, as Honorary Chairman, W. A. Parks (Chairman), Frank Arnoldi, T. G. L. Barnes, C. L. Burton, C. A. Chant, Dr. F. Le M. Grasett, Arthur Hewitt, J. B. Tyrrell, W. R. Worthington and J. Patterson (Secretary). A portrait was chosen as the most fitting memorial, to be presented as nearly as possible on the date of Sir Frederic's retirement.

In opening the meeting the chairman expressed regret that the influenza epidemic had seriously interfered with the plans for the evening. Mr. Alex. Johnston, the Deputy Minister of Marine, under whose jurisdiction the Meteorological service is conducted, was prevented from attending, and had telegraphed the Secretary his regret at his inability to be present. The Bishop of Toronto, was to have addressed the meeting but was confined to his bed. Mr. Barnes,

representing the St. George Society; Mr. Hewitt, representing the Royal Canadian Institute; and Prof. Chant, representing the Royal Astronomical Society, all regretted their inability to be present owing to the same cause. The two latter sent letters of appreciation which were read, and Mr. Patterson, Prof. McMurrich, Mr. C. L. Burton and Mr. E. B. Calvert spoke on behalf of the organizations they represented.

The chairman asked Mr. Patterson to give an outline of Sir Frederic's work.

Sir Frederic Stupart's Work by J. Patterson

Meteorology, or the study of the weather, may be divided into three great epochs. The first lasted from the dawn of civilization to the discovery of the barometer and thermometer in the seventeenth century. To this period belong most of the weather proverbs, some based on real physical phenomena but most on ignorance and superstition. The second epoch which lasted to about the middle of the last century marks the dawn of the real study of the physics of the atmosphere, while the third began about 1870 with the introduction of the weather map. This was the beginning of modern meteorology. Sir Frederic entered the Service a few years afterwards and thus began his career almost at the beginning of this third and last epoch. He thus has not only witnessed but has been an active participant in the tremendous development that has taken place in the interval. As I understand that he intends to give a short sketch of the Service I shall not deal with this side of his work, except to say that when the Weather Maps were first prepared observations were received from six stations extending from Lakes Huron and Erie to Quebec, and from fifteen stations in the United States. These maps disclosed the characteristics of violent storms and were immediately used for the purpose of issuing warnings of approaching storms to mariners. The Washington Bureau issued the warnings at first but by 1876 the Canadian Service had developed sufficiently to take over the work and in September 1876 Sir Frederic had the honour of issuing the first storm warning message sent out by the Canadian Service. About a month later Mr. Charles Carpmael and Mr. B. C. Webber issued the first forecast. At that time the weather charts were new and the area from which observations were ob-

tained was very limited and little was known about the interpretation of the charts.

The problem was to study and investigate these charts and discover their interpretation in order to forecast the weather and issue storm warnings which were primarily for the use of mariners. The investigation developed along two lines; first, by ever widening the area from which observations could be obtained, and second, by studying to find out the characteristics and behavior of the various systems disclosed on the charts. This latter has been one of Sir Frederic's greatest contributions to meteorology, and the present methods of forecasting and the splendid success achieved therein have been due to his directing genius. In the course of the development he has travelled extensively over Canada, and attended meteorological conferences in Europe in order to keep the Service in a high state of efficiency. The dream of meteorologists for many years, and one that still awaits fulfilment, is the production of a world weather map. Sir Frederic has been one of the leaders in this movement and was the first to make a serious attempt at realizing this dream by producing weather maps for the greater part of the northern hemisphere. For this purpose observations are received daily from a number of stations in Europe, Greenland, Iceland and the Azores, as well as from ships at sea on both the Atlantic and Pacific. This map has laid the foundation for forecasts for the North Atlantic for the use of aviators and is a very great contribution to meteorology.

Sir Frederic has thus been one of the pioneers in meteorology and I would ask you to try and visualize the situation as it existed when he began his work. There were weather prophets then as now who thought they could predict the weather for a year or more in advance, and when adventurous scientists began to apply scientific methods to forecasting they were looked upon as belonging to this class. So great was this prejudice that the noted Royal Society of London reprimanded severely Admiral Fitzroy for levelling himself to what they considered quackery, and when the work was transferred to them on his death they actually forbade the issuance of storm warning for many years. Meteorologists have thus run the gauntlet of prejudice, contempt and ridicule as most pioneers have to do. The attitude was well expressed in a

poem published many years ago in which a farmer was represented as purchasing all sorts of "contraptions" to make the rain come down, and succeeded so well that his land was flooded, he himself was drowned and all efforts to stop the rain were unavailing until an appeal was made to the Weather Bureau which stopped it by a single word by simply forecasting "rain". All the pioneer phases have been passed through. By patience and careful study the forecasts were gradually improved and slowly but surely public confidence was established and the Service raised to one of very great importance to the country.

While this has been Sir Frederic's great life work, he has at the same time made a careful study of the climate of the country and has an unrivalled knowledge of it. He has been greatly interested also in the causes of the different types of Canadian winters and believes that they depend to a great extent on the temperature of the water in the North Pacific. To study this, he has had the Service investigate the methods used in obtaining sea-water temperatures and as a result a method has been devised that has not only proven very satisfactory but is rapidly becoming the standard method of obtaining accurate sea-water temperatures from ships.

His contributions to meteorological literature have appeared in the Transactions of the Royal Society of Canada, the Transactions of the Royal Canadian Institute, the Journal of the Royal Astronomical Society, the United States Monthly Weather Review, the Bulletin of the American Meteorological Society, Polar Research (published by the American Geographical Society), and the Canada Year Book. These contributions form an important contribution to our knowledge of the Canadian climate and of the character of our winters.

In closing I wish to say a few words as a member of the staff, and I am sure that I speak for all when I say that the Director has always been kind and considerate of his staff, always patient, ever upholding and advancing their interests, and has been a wise counsellor and friend. We all hope that he may be long spared to enjoy a well earned rest. May I also add the hope that he may now find the time to give us a history of the Service. He is connected, through his acquaintance with his predecessors, with the Service from the beginning in 1842, and can thus from personal knowledge give this history to date and no one else can do it.

By Mr. Arthur Hewitt, past President of the Royal Canadian Institute:

Sir Frederic Stupart holds the unique honour of being the oldest active member of the Royal Canadian Institute. For nearly fifty years he has kept up a sustained interest in its work. He served faithfully and well as an officer at various times. He was Secretary from 1898 to 1900, Vice-President from 1901 to 1905, and President from 1906 to 1908. Besides which he served on the Council of the Institute over the long period of 21 years from 1896 to 1917.

Added to his contribution in the administrative work of the Institute, must be mentioned the large number of scientific articles which Sir Frederic wrote in the Institute publications, one of the earliest being in 1886 when he presented a paper on "The Eskimo of Hudson Straits."

By Professor C. A. Chant, for the Royal Astronomical Society

Sir Frederic Stupart has been a member of the Royal Astronomical Society of Canada since its formal organization in 1890, and was its president in 1902 and 1903. Several of his contributions to science have been printed in its *Journal* and the Society has for years been under obligation to him for his courtesy in allowing the meetings of its Council to be held in the Meteorological Office.

Professor J. P. McMurrich, representing the University of Toronto spoke with sincere feeling and appreciation of the valuable contribution made by Sir Frederic in the development of the Meteorological Service. He pointed out that at first the Meteorological Office, then the Magnetic Observatory, was very closely associated with the University and that the Director was also a Professor. In his day there was a course in meteorology but he did not think very much of the course then given. He regretted the severance of the Service from the University and felt that there was now a real place and need for a course in meteorology in the University.

Mr. C. L. Burton, President of the Board of Trade, expressed the feeling of the business world to Sir Frederic and of his great activities in bringing the Service up to the present standard, and confidence of the business men.

By Mr. E. B. Calvert, Chief Forecaster, representing the United States Weather Bureau

It is a high privilege to participate on this occasion and a great pleasure, but the pleasure is mingled with regret that it is I and not Dr. Marvin, the Chief of the Weather Bureau, who is representing the meteorological service of the United States. Dr. Marvin wished to come and would have come were it not for the fact that to-day he had to appear before a committee of our Congress in connection with an important matter of legislation which required his presence. Dr. Marvin wishes me personally to express the felicitations of himself and his staff, and to read a letter he has addressed to Sir Frederic. With your permission I shall read it.

January 5, 1929.

Dear Sir Frederic:

In appreciation of the kind invitation of the Committee to be present personally on this occasion, I desire to extend my cordial thanks, also to express my regrets that unavoidable appointments prevent me from being present in person.

As the invitation indicated that, in such an event, a letter from me to be read at the meeting would be appreciated, I am writing this letter, which I will ask to be read by Mr. Edgar B. Calvert, in charge of our Forecast Division, whom it has been a pleasure for me to detail to attend the meeting as my representative, and who joins me in congratulations and felicitations.

I always experience a thrill of gratification when I recall the remarkable spirit of co-operation that has marked fifty years or more of the world-wide relationships between meteorologists. Nowhere else has this been more completely exemplified than in the relations between the United States meteorological service and that of Canada.

In the case of the latter, systematic and official observations began at the Magnetic and Meteorological Observatory of Toronto long before a regularly organized effort can be pointed to in the United States. Nevertheless, the organization in the United States of the present meteorological service in 1870 was simultaneously paralleled by a similar organization in Canada, and for nearly sixty years these services have worked in friendly co-operation, thirty-five years of which, on the part of Canada, have been under the leadership of our beloved Sir Frederic Stupart.

The occasions which have brought Sir Frederic and myself together personally have been relatively few, but the intercommunications, official and otherwise, have combined to create a warm feeling of friendship for him which is destined to continue throughout my life.

No one is in a better position than we of the United States Weather

Bureau to speak authoritatively of the efficiency and fidelity with which the Canadian Meteorological Service has carried out its responsibilities under Sir Frederic's leadership.

The interchange of meteorological reports across the broad stretch of our Canadian border line has been practically uninterrupted and continuous, and the Dominion may well feel proud of this Service, as the United States is glad to commend it as one of the foremost and leading meteorological organizations of the world.

It is our earnest hope that Sir Frederic will greatly enjoy the period of rest and release from the exacting responsibilities of his directorship, and that the future holds for him many years of health, happiness and prosperity.

Sincerely yours,
(Signed) C. F. Marvin,
Chief of Bureau.

And now may I say a few words on my own behalf. I might be considered a veteran in meteorological work, but Sir Frederic exceeds my record by several years and far transcends it in accomplishments. During all the thirty-nine years I have been connected with the U.S. Weather Bureau, Sir Frederic's name has been almost as well known to the men of our service as those of our own chiefs; in fact it has been difficult for many of us to think of the Canadian Meteorological Service and the U.S. Weather Bureau as separate organizations. So far as contact and intimacy of operations are concerned they have been a unit. Meteorologically speaking, there has been no boundary line. For years many Canadian weather reports have come to us before being transmitted to Toronto; in other cases the reverse has been true. There has been a freedom of exchange of weather information, plans of operation, and advices that could have been no stronger if the two meteorological organizations had been one. As Dr. Marvin has stated, I doubt if there ever has been a better exemplification of good understanding and cordial relationship between two great nations.

It was not my good fortune to come into personal contact with Sir Frederic until a few years ago. Since then I have had occasion to meet him many times concerning problems which were of much importance to our respective services. It was his spirit of co-operation and helpfulness (which went far beyond the requirements of official courtesy) that contributed in no small measure to a successful solution of those problems. Thus, you can understand

why it gives me so much pleasure to convey to him my own congratulations, as well as those of my Chief and the entire personnel of the Weather Bureau, and to wish him many years of happiness and good health while taking the rest which he has so richly earned. I know that I am not mistaken when I say that his rest will not be devoted to idleness and inaction, and that he will continue to interest himself in meteorology towards which he has contributed so much to give it a high place among the sciences. His rest will be what the poet had in mind when he wrote:

Rest is not quitting
The busy career;
Rest is the fitting
Of self to one's sphere;
'Tis loving and serving
The highest and best,
'Tis onward, unswerving.
That is true rest.

Presentation of the Portrait by Professor W. A. Parks, Chairman

We cannot see far into the future, but when we look back, we are impressed by the profound effect on the present of events of seeming insignificance in the past. In all sciences involving time the best guide to the future is a knowledge of the past. While it would be a great mistake to reduce the whole science of meteorology to a matter of weather forecasting, that aspect, nevertheless, is a very important one in the government service. The old almanacs were not entirely devoid of virtue; they were founded on the average of past years. We believe that summer will come again, because we have behind us a long succession of summers and winters. Faith is the expression of experience. We have faith because we have knowledge, and what is true of events is true of men. A man's past life is the best guarantee of his future.

Those of us who have had the honour of a long acquaintance with Sir Frederic Stupart know his past life—his devotion to duty, his unfailing kindliness, his uniform courtesy. We have faith, certain faith, that the mere circumstance of his retirement from active service will in no way affect the man himself, our relations with him, or the fine flavour of his friendship.

We must be sincere, however; it is no small matter for a man to relinquish his life's work. Next to his birth and his marriage

a man's choice of his profession marks the most important point in his career. The withdrawal from that profession, even though partial, must of necessity be accompanied by a degree of sadness that it would be insincere to overlook. I know Sir Frederic well enough to say that he is not retiring from active service—leaving the work that he loved so long, without profound regret. We cannot remove that regret but we may alleviate it. We can remind Sir Frederic that he is still a Fellow of the Royal Society of Canada, and that he was President of Section III of that Society in 1912. We can remind him that he is a member of the International Meteorological Committee and its Vice-President. We can remind him of the Toronto organizations of which he is a member: the Royal Canadian Institute, the Royal Astronomical Society, the St. George Society, the Toronto Golf Club, and others. We can assure him that all these institutions will feel honoured by his presence and will continue to hold him in the highest esteem.

I need not remind him that he still has Lady Stupart—a wife in the highest sense of the word. In many circles and on many occasions I have heard conversations as follows: "There is Sir Frederic, where is Lady Stupart?" "Oh, she is not far away." Faithful helpmeet, inseparable companion: any congratulations to Sir Frederic must be extended to Lady Stupart as well.

It has been said of Shakespeare that he had "small Latin and less Greek." Therein I resemble Shakespeare, but I should have to confess to little Latin and no Greek. There are, however, a few scraps of Latin still remaining to me. One of these seems peculiarly appropriate as it expresses far better than any words of mine the general feeling with respect to Sir Frederic Stupart—*Integer vitae scelerisque purus*— freely translated "a man of pure life and free from blemish."

I shall always be grateful to my colleagues on the committee for allowing me the honour of making this presentation. It is with great pleasure that I ask Senator McGuire on behalf of the Dominion Government to accept this portrait of Sir Frederic Stupart.

Prof. Parks then unveiled the portrait and Miss Eleanor Barton presented Lady Stupart with a magnificent bouquet of roses.

Acceptance of the Portrait by Hon. Senator W. H. McGuire for the Dominion Government

I wish to express my great regret that the Deputy Minister of Marine could not be here. Had Mr. Johnston not been prevented by the death of Hon. G. H. Murray from attending, he would have been delighted to say many things in praise of Sir Frederic Stupart. For myself, I wish to express my personal admiration for Sir Frederic and I accept, on behalf of the Dominion Government, his portrait, and ask that it be hung in the Meteorological Office in commemoration of Sir Frederic's life work—a work that was always sincerely appreciated by the Dominion Government.

Response by Sir Frederic Stupart

When it became known to me that some of my friends wished to have my portrait painted, I could not see why. Up to that time it had never occurred to me that anyone would be interested enough in me to do me this signal honour. My personal inclination is just to thank you for your very great kindness and expressions of goodwill to me and Lady Stupart, but I feel more is expected, and therefore I propose to give you a brief outline of the history of the Service and my connection with it.

About 1837 scientific men in Europe were giving much attention to terrestrial magnetism, and the British Association and the Royal Society of London conjointly petitioned the British Government to establish observatories in various parts of the world, under officers of the Ordnance Department of the Army, the sites chosen being, St. Helena, Cape of Good Hope, Tasmania and Toronto. The Toronto contingent was placed under Lieut. Riddell of the Royal Artillery, who with three non-commissioned officers came to Canada in 1839. The observatory was built on the site now occupied by the Physics Building of the University of Toronto, the two piers in front of the building marking the site of the astronomical instruments. Work began in 1840. Lieut. Riddell was invalided home in 1841 and Lieut. Lefroy, R.A., came from St. Helena and took charge. Observations both magnetical and meteorological were made six times a day. Lefroy remained until 1852 when he returned to England, and the observatory was taken over by the Provincial Government and placed in charge of Prof. J. B. Cherriman, who was professor of Natural Philosophy in University College. Prof. Cherriman remained for only four years

and was succeeded in 1856 by G. Templeton Kingston, a graduate of Cambridge, as Director of the Observatory and Professor of Meteorology. Prof. Kingston carried on the regular observatory work for some years, and then began the organization of a meteorological service for Canada, which was developing rapidly.

In 1872 Professor Kingston obtained an assistant from England in the person of Charles Carpmael, a gentleman who had graduated with high honours in mathematics in Cambridge.

Prof. Kingston and Mr. Carpmael concluded that the first essential was to obtain some young men who should be trained in meteorology with the weather map as the basis of study, and I was one of these. But some of the facts which led to Prof. Kingston asking me to become a member of his staff, long antedated even the establishment of the observatory in 1840. Back in 1827 my father, who was the son of a naval officer, entered the Royal Naval College at Portsmouth as a cadet; in the following year there came to the college another cadet named George Templeton Kingston and a friendship was established between the two boys. My father entered and remained in the service until after the Crimean War, but Kingston only remained in it a short time; he then went to Cambridge and later on we find him in Quebec in charge of a naval school. He it was who was appointed to the Observatory in 1856. Later on my father and he renewed their friendship in Toronto and when the time came I was offered a position in the Observatory.

I entered the Service in November 1872, and later on my special colleagues in meteorology were B. C. Webber and H. V. Payne, and we three worked together on the weather maps, and as the years passed there was rivalry as to which of us could make the best weather forecasts, and I do not think it was ever decided to everybody's satisfaction. I bear witness that much of the best forecasting was done by Mr. Webber. We three established and inspected the meteorological stations throughout the Dominion and naturally were all familiar in an unusual degree with the various Canadian provinces.

I have been blessed with many true friends. Prof. Kingston was a dear old gentleman always ready to help one in difficulties and I greatly admired him. Carpmael took me in hand as soon as I entered the Service; he coached me in mathematics and chemistry,

and did all in his power to improve my education. He was a very true friend. Webber, as I have said, worked hand in hand with me and in later years became Assistant Director. In 1894 Mr. Carpmael went to England on sick leave, leaving me in charge of the Service. He died in October and toward the end of December 1894, I was appointed Director. During this long period the Service has grown tremendously, and I have been blessed with a splendid staff.

But there have been others to whom I owe a debt of gratitude and these have been the Ministers and Deputy Ministers in Ottawa under whom I have served. The Ministers during my period of office have changed often. I was appointed by Sir Hibbert Tupper, a splendid man, and I recall with peculiar pleasure Sir Louis Davies. But the executive head of the Department is the Deputy Minister and in 34 years I have only served under four and in every case it has been a pleasure. Particularly, I owe much to Mr. Johnston, who has been a true friend. Every member of the Department of Marine knows that if a civil servant in his Department does his duty and does it well, his chief knows it and will reward his endeavours. I thank Mr. Johnston with all my heart.

My relations with the United States Weather Bureau have always been most pleasant—there has never been anything but cordiality and most agreeable co-operation. I feel honoured in having the Assistant Chief of the U.S. Weather Bureau here with us tonight. Happy relations have also been maintained with other countries—I have been at every Meteorological Congress since 1896, eight in all, and have met all the meteorological directors.

I believe that beyond the grave man's activities do not cease; they probably multiply, and if this be so, I only hope that I may meet and work with some of those with whom I associated in this life. I shall hope to see Kingston and Carpmael again and many of the others. All through my life I have taken a keen interest in sports, in boat sailing and yachting chiefly until 15 years ago, when I gave up sailing and have since played golf, perhaps very badly.

The only thing which rather perturbs me is the fact that my portrait is, I understand, to hang in this building without corresponding portraits of my predecessors in office; they, of course, laid the foundations of the Service and I have built thereon.

In conclusion I thank you all, my friends, with all my heart.

THE PLANET EARTH

A Concise Tabulation of Many Items of Interest to the Amateur

By W. G. Colgrove

Myth—In Greek mythology Ge or Gæa was the wife of Uranus and the mother of the Titans, including Cronos and Rhea, who were the parents of that powerful dynasty of myth divinities led by Zeus and Poseidon.

Symbol—⊕ Indicating the main circles of the equator system of co-ordinates.

Markings—To observers on other planets our oceans and continents would constitute the markings, variegated in colour, while the clouds at times would intervene and hide the real surface.

Stellar Magnitude—To such observers our planet, at nearest approach, would appear very brilliant, just as our moon and Venus appear to us. We know the earth shines because light from the earth is reflected to the moon and is then returned to us by its dark side.

Linear Diameter—As repeatedly measured by different methods, the polar diameter is close to 7,900 miles, the mean 7,917 miles and the equatorial 7,926 miles. It would take about 12,000 such worlds placed side by side to reach the sun.

Circumference—Equatorial circumference, 24,900 miles.

Area of Surface—197,000,000 square miles, of which 56,000,000 are land and 141,000,000 are water.

Volume—260,000,000,000 cubic miles. It would take about 1,300,000 of them to equal the volume of the sun.

Mass—This is somewhat more than 6,000,000,000,000,000,000,000 tons or 1/332,000 of the sun. This has been measured by a number of methods, such as Maskelyne's mountain method, Cavendish's torsion balance, Airy's mine experiment and recently at the Bureau of Standards at Washington, D.C. It is the unit of planetary mass.

Density—At the surface the density is about 2.3 times that of water while at the centre it is estimated to be very much denser with an average for the entire earth of about 5.6 times that of water.

Surface Gravity—This is, of course, the gravitational attraction

for bodies on the earth's surface and differs slightly at different locations according to altitude and latitude. Another unit of planetary measurement.

Velocity of Escape—6.95 miles per sec. This is the speed at which a body would have to travel from the surface of the earth in an effort to overcome the power of gravitation and escape into outer space.

Rotation Period—The true period is 23 hours 56 mins. 4 secs. The rotatory motion produces our days and nights the relative lengths of which vary at different times of the year on account of the inclination of the earth's equator to the plane of its orbit. The proofs of rotation are numerous, as shown by a variety of observations and experiments. The most important of these are: the shape of the earth, the eastward drift of falling bodies, the deviation of air currents, the analogy to other planets which rotate, the various pendulum experiments and the decrease of gravity from the poles to the equator.

Equatorial Velocity—About 1,440 feet per sec., 1,040 miles per hour and 24,910 miles per day.

Oblateness—1/297. This fraction is found by dividing the difference between the equatorial and the polar diameters by the equatorial diameter. It amounts to about 26 miles.

Atmosphere—The density of the atmosphere at the earth's surface averages about 1/773 of water. Its height is indefinite because its density decreases as we ascend. Calculated from the duration of twilight which ceases when the sun reaches 18° below the horizon, it is about 50 miles high, but from other observations it is known to be more than 100 miles. Its total weight is about 6,000,000,000,000,000 tons or 1/1,000,000 of the entire earth. Its pressure at sea level is about 15 pounds per square inch. Connected with the atmosphere are such phenomena as the refraction of light (as in a mirage) the aurora, the twilight, the wonders of sunrise and sunset and electrical and wind storms.

Solar Radiation—The sun disperses into space a vast amount of light and heat. Of this we receive only a mere beam about 8,000 mls. in cross section which is about 1/2,000,000,000 of the total sent out.

Temperature—Our earth still possesses great internal heat, but it is not sufficient to prevent the planet from becoming a frigid orb

were the sun's radiation withdrawn for a short time. The sun's heat reaches its maximum at about August 1 and its minimum at about Feb. 1. This produces what is termed the lag of the seasons.

Distance from Sun—About 91,400,000 miles, 92,900,000 miles, and 94,400,000 miles. These are the perihelion, mean and aphelion distances respectively.

Diameter of Orbit—About 186,000,000 miles. It takes a ray of light 1,000 seconds to cross it.

Circumference of Orbit—About 570,000,000 miles. It is almost circular, the eccentricity being very small.

Sidereal Period of Revolution—365 days 6 hours 9 mins. 9.5 secs. of mean solar time. The tropical year or year of the seasons is slightly less, 365d. 5h. 48m. 46s., while the anomalistic year, which is the time between two successive perihelion passages, is 365d. 6h. 13m. 53s. The fact that the earth revolves in an orbit round the sun is shown by the annually periodic variation in the radial velocities of stars, by the annual parallactic displacement of the stars, and by the aberration of light. Besides its rotation and revolution, the earth has several other motions, including its vast voyage with the sun and other planets towards Vega.

Orbital Velocity—Mean 18.5 miles per sec., 66,600 miles per hour, and about 1,660,000 miles per day. This is about 100,000 feet per sec.

Inclination of Equator to Orbit—23° 28′. This is the cause of our varied seasons. In spring about 93 days; in summer about 93½; in autumn about 90 days, and in winter about 89 days. It is interesting to note that during our midsummer the north pole of the earth receives one-fourth more heat than does the equator per unit area.

Pole Star—Polaris, although the true celestial pole is some distance from it. During the past 4,900 years the direction of our pole has been changing from Alpha of the Dragon around to Polaris and it will continue in that direction for 200 years more. Then it will depart on its journey towards Alpha of Cepheus and thence toward Vega.

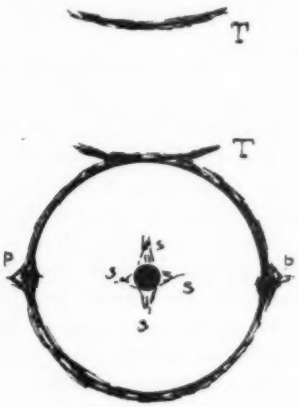
Perihelion and Aphelion—It is at perihelion early in January and at aphelion early in July of each year.

Lambeth, Ontario.

A LUNAR HALO SEEN AT MONTREAL

BY T. N. WHITE

On Sunday evening, March 24th, at about 7.30 to 8.00 p.m., I had the good fortune to observe from Mount Royal a rather unusual halo formation about the moon. The sketch below shows the general appearance.



Lunar Halo seen at Montreal, March 24, 1929 by T. N. White.

The elevation of the moon was about 50°. The sky was hazy. The parselenae *p*, and the tangent arcs *T*, were clearly observable; the outer (46°) halo was not visible. The streamers *s* were uncertain, but I place some confidence in their observation because I did not at the time know that they were possible.

On Sunday the weather was fine. Monday brought violent showers, and several sharp thunder storms—rather peculiar weather for this time of year.

McGill University.

THE MODERN PHOTOGRAPHIC TELESCOPE AND THE NEW ASTRONOMICAL PHOTOGRAPHY

By G. W. RITCHEY

PART VI.—THE NEW ASTRONOMICAL PHOTOGRAPHY (*Continued*)

64. We are considering the use in celestial photography of the 5-metre (16.4 foot) Fixed Universal telescope, the general specifications for which are given in paragraphs 28-32 of my preceding (January, 1929) article in this JOURNAL. With each of the focal lengths of this telescope—whether the observers are photographing faint nebulae or fields of very faint stars with a low-power combination of mirrors, star-clusters or star-fields for the most exact measurement attainable, with a medium or high-power combination, or bright planetary nebulae, planets or the moon with an extremely high-power combination, they use in each case identical refinements of every detail of guiding, occulting, focusing, refocusing, etc.[1] I explain again that this guiding is for the purpose of correcting continually for the very small, rapid, irregular movements of the field of celestial objects being photographed, which movements are due to the lack of entire tranquility and homogeneity of the atmosphere through which the telescope must look out.

65. In the preceding article I discussed many of the refinements by which the *telescope* images of this reflector will be greatly improved. In the latter part of that article I described briefly some of the new methods by which we shall greatly improve the images on the photographic plate. I have designated as *observers* the highly-trained technicians who will actually *use* in celestial photography this super-telescope. We have seen that for each combination of mirrors the field is always horizontal, stationary and non-rotating. These conditions permit the observers to do their strenuous work of guiding, occulting, focusing, refocusing, etc., always in a comfortable office, in a *comfortable, chosen* position, as a master organist or pianist *plays*. And as an organist, playing

[1]This JOURNAL, November 1928, pages 366-368.

a modern, electrically-operated pipe-organ experiences no difference in the mechanical effort—the physical labour of his playing, whether he is using *one* set of pipes of his organ or *fifty* sets, so to the observer using the horizontal, electrically-operated guiding-mechanism it makes no difference whether he is using, for example, a four-inch, circular photographic plate with a one-metre Schwarzschild fixed telescope, or a twenty-inch similar plate with a five-metre, similar telescope. The action of the keys used in guiding is equally light in all cases, and the response of the mechanism to the observer's touch is with the speed of light. I have frequently observed among our musical friends in Paris the incredible skill, speed, smoothness, accuracy and whole-souled *earnestness* of their playing, together with the marvellous *response* of their modern instruments, as they interpret the works of the great masters. And as frequently, in comparison, I have thought of the manner in which astronomers use their great telescopes in their work of making photographs with which to interpret the works of the Infinite Master.

66. We come now to the extremely important subject of special photographic emulsions. We shall consider the requirements in this regard of the component telescopes, with various focal lengths, of the Fixed Universal reflector of 5 metres (16.4 feet) aperture, as illustrating all requirements. We shall consider at present only the telescopic images given by photographic (blue-violet) light (wave-length 0.435 micron).

67. We note, first, that the *angular* diameter of the diffraction disks due to this aperture and wave-length is 0″.019 for any and all of the focal ratios of this telescope[2]; second, that the *linear* diameters of the diffraction disks vary directly as the focal lengths used, or from 1.35 microns (0.00005 inch) for the shortest focal length, 45.1 feet, to 44.0 microns (0.00175 inch) for the greatest focal length, 1476.4 feet[3]; third, that the surface-intensities of the diffraction disks of a given star in the axis vary inversely as the squares of the focal lengths used; for example, in the proportion of 1071 for the 45.1-foot focal length to 1.0 for the 1476.4-foot focal length; fourth, that the surface-intensities of the images of a given celestial object with extended surface, such as a planet, the moon, any nebula, a comet, etc., vary inversely as the squares of the focal

[2]January article, paragraph 23. [3]January article, paragraph 14.

lengths used, or in the proportion of 1071 for the 45.1-foot focal length to 1.0 for the 1476.4-foot focal length.

68. The Schwarzschild combination with focal ratio 2.75 to 1, giving a focal length of 45.1 feet, will be used for photographing large fields of extremely faint stars and nebulosities. The scale of the original negatives is about 1.07 times greater than that given by the 100-inch Mt. Wilson reflector when used as a Newtonian. The convex field can be used as large as 2°.0 or 2°.5 in diameter, with telescopic star-images which are practically diffraction disks 1.35 *microns* in diameter, and therefore of very great intensity, over the entire field. With this focal length one millimetre at the focus equals about 15″.1; therefore a field of 2°.0 or 7200″ diameter is 477 mm. (about 19 inches) in diameter. I ask astronomers, as well as all of my readers, to note carefully this marvellous Schwarzschild field. It is slightly *convex;* the sensitive emulsion of the photographic plates used with it is coated on the *concave* side of a thin, concavo-convex, ground and polished, uniformly thin plate of boro-silicate crown glass, which is used in the telescope with its *convex* side toward the incident cone of light. The spherical curvature of this ground and polished plate coincides, within 0.0001 inch, with the true spherical curvature of the Schwarzschild field of smallest images. Focusing and refocusing are done *quickly* and *frequently* by a method recently developed in my laboratory, and are also accurate to 0.0001 inch.

69. Such large celestial objects as the Pleiades (diameter of field 1°.5); the Great Nebula in Andromeda (field 2°.0); Messier 8 *Sagittarii* (field 1°.3); Messier 33 *Trianguli* (field 1°.3); N.G.C. 6960 *Cygni* (field 1°.3); N.G.C. 6995 *Cygni* (field 1°.5); N.G.C. 1499 *Persei* (field 2°.0); the Great Nebula in Orion (field 1°.5); the nebulosity immediately surrounding *Rho Ophiuchi* (field 2°.0); the great globular clusters *Omega Centauri*, 47 *Tucani* and Messier 13 *Herculis* (each field 1°.5); Messier 3 *Canum* and Messier 5 *Librae* (each field 1°) will each be photographed *entire*, with definition practically as perfect at the edges as at the centre of the field, and on a scale of approximately 9.5 inches to each degree.

70. Let us compare these photographs with my best long-exposure ones, such as those of Messier 13 *Herculis* and N.G.C. 6995 *Cygni*, made in 1910 with the 60-inch reflector with its aperture

reduced to 50 inches (focal ratio therefore as 6 to 1). Let us consider, first, the relative surface-intensities of the *telescopic* diffraction disks of a *given* star in the axis of each telescope. We note, as a first step, that in the case of two telescopes having 50 inches aperture, one with a ratio of focal length to aperture as 6 to 1, the other with a corresponding ratio as 2.75 to 1, the telescopic diffraction disk given by the latter is smaller in *linear* diameter in the proportion of 2.75 to 6; it is smaller in area in the proportion of 1 to 4.76; and it is higher in surface-intensity in the proportion of 4.76 to 1. As a second step, we note that in the case of two telescopes each having a ratio of focal length to aperture as 2.75 to 1, but one having an aperture of 50 inches, the other of 5 metres, or 196.85 inches, the *linear* diameters and therefore the areas of the telescopic diffraction disks in the axis given by the two telescopes *are equal*, but the surface-intensity of that given by the larger aperture is higher in the proportion of the squares of the apertures, or as 15.5 to 1. As a third step we note that in the 50-inch reflector there are only two reflections from the silvered mirrors, while in the 5-metre universal telescope there are two *additional* reflections (oblique reflections) from the two 6-metre plane mirrors in the dome. Allowing 13 per cent. as the *additional* loss of light due to the *four* reflections instead of the *two*, and taking account of the fact that the additional reflections are oblique, we now have as the product of the three factors derived in the three steps just described, $4.76 \times 15.5 \times .87 = 64.2$. There is an additional loss of light in the Schwarzschild telescope due to the presence of the thin, slightly-curved plate of boro-silicate crown glass which carries on its back (concave) surface the sensitive film of emulsion. If we allow 6.5 per cent. as the loss of blue-violet light due to the one reflection from the front (convex) surface of this plate, together with the loss due to absorption in this plate, we have $64.2 \times .935 = 60.0$. This factor represents the *gain* in surface-intensity of the telescopic diffraction disk in the axis of the 5-metre (16.4-foot) Schwarzschild telescope of 45.1 feet focal length. Let us note again that this comparison relates to the telescopic images, without reference, as yet, to the work of photographing them.

71. Since the out-of-axis images in the best form of Schwarzschild telescope (the one here used) are practically free from astig-

matism and are therefore practically diffraction disks over the entire field, the gain in surface-intensity of these images as compared with the surface-intensity of the out-of-axis images given by the 50-inch aperture of the Newtonian telescope is much greater than 60.0 times, and this gain is progressively greater for images farther and farther from the axis.

Continuing now the comparison of the surface-intensities of the telescopic images in the axis, let us consider the very important question as to whether we can expect to realize *in actual use* of the larger instrument the gain of 60-fold in surface-intensity arrived at above. In the fourth article of this series (page 371) I said that to accomplish this result and similar ones we must *analyze* and systematically study *all* of the conditions which affect the character of the images, and that we must *find* and *apply* the remedy for all of those conditions which are injurious. Let us turn to paragraph 24 of my preceding article and note there the list of seventeen major conditions which affect the character of the telescopic images. These conditions can be arranged in three groups: First, those which relate to the quality and the permanence of optical figure of the mirrors; second, those which relate to the telescope-mounting, and especially to its freedom from the injurious effects of flexures and of temperature changes, which destroy the optical alignment of the mirrors; and third, those which relate to better exterior conditions—those of atmospheric definition and transparency.

72. Owing to the permanence of optical figure of cellular, ventilated mirrors built up from small, selected units of low-expansion vitreous material; to the freedom from injurious effects of flexures and of temperature changes made possible to an incomparable degree in the fixed, universal type of reflecting telescope; and to the better atmospheric definition at the best observatory sites already found in Arizona, we shall realize, in actual use of this telescope, *all* of that gain of 60-fold in the relative surface-intensities of the telescopic diffraction disks. Were it not that this gain of 60-fold is defined—*limited*, by the comparative apertures and by the comparative focal ratios of the two telescopes, we could go, without great difficulty, *far beyond* this definite gain, by means of the three groups of improvements just named, in which I include

better atmospheric *definition*, but do *not* include better atmospheric *transparency*. The effect of better atmospheric transparency upon the light-intensity of the images is *not* limited by the two instrumental conditions just named. A long-continued series of rigorous comparative tests made with a 16-inch reflecting telescope at different altitudes and in many different locations shows that the greater transparency for blue-violet light at the best sites found in Arizona will nearly *double* our former gain of 60-fold. This is due to (1) greater altitude (about 7,500 feet); (2) extremely dry, semi-desert conditions; (3) complete freedom from smoke, haze and electric lights nearby, populous cities; and (4) using the telescope always within 15 to 18 deg. of the zenith. I shall therefore adopt the *ultra-conservative* factor of 100-fold, or five magnitudes, as the gain in surface-intensity of the axial telescopic images of the 5-metre telescope (with focal length 45.1 feet) used at the best Arizona site, above the surface-intensity of the corresponding images given by the 60-inch reflector at Mt. Wilson with its aperture reduced to 50 inches.

73. Let us next consider whether it is possible to utilize *all* of this gain of 5 magnitudes in *making celestial photographs* at the 45.1-foot focus of the larger telescope. Those of my readers who are keenly interested in the answer to this question, and to similar ones relating to the new celestial photography, will read again paragraph 25 of my preceding article, which gives a list of many *additional* conditions which affect the character of the images on the photographs. And they will note again my solutions of very many of the difficulties relating to these conditions. These solutions are briefly described in paragraphs 42 to 63 of my preceding article—solutions which I myself have developed and demonstrated during ten years' use of the most powerful telescopes in celestial photography, and during more than thirty years of research in my optical and astronomical laboratories.

74. Let us note again that we are now comparing the *new photographs* with the best of those made with the 60-inch reflector with its aperture reduced to 50 inches, and with all of the refinements developed up to 1910. In my sharpest photographs thus made with the 50-inch aperture on the finest nights, of celestial objects passing near the zenith of Mt. Wilson, with exposures

extending from two hours east to two hours west of the zenith—exposures usually continued for two or three nights, and using commercial photographic plates having moderately fine grain (*Seed 23* plates), I was able to photograph, at the centre of the field, stars as faint as 21.5 magnitude of the Harvard scale, their images on the negatives measuring very nearly 0″.8 in diameter. But with the conditions just listed, the diameter of the telescopic diffraction disks given by the 50-inch aperture, in blue-violet light, at the precise focus, is 0″.08—that is, ten times smaller in diameter or 100 times smaller in area than the best photographs of them. This great discrepancy was due to the following causes: First, errors of *focus*, namely, (*a*) those due to the impossibility of focusing accurately on the irregular surfaces of commercial photographic plates; and (*b*) those due to continual small changes during the exposure, of the plane of the plate-holder with reference to the telescopic field, due to continual small changes of length (a temperature effect) of the *unprotected* steel tube. Second, small errors of *guiding* due to (*c*), impossibility of correcting, with the *highest* efficiency, with the type of guiding-mechanism used with the 60-inch reflector, for the rapid, minute tremors and for the continual fluctuations of sharpness, of the telescopic images as seen in the guiding eye-piece, even on the finest nights, with the full resolving power of the 50-inch aperture[4]; (*d*) impossibility of the most efficient guiding and occulting, due to the continually changing relative *position* of the guiding-mechanism and the observer in the case of the *equatorial* Newtonian reflector. Third, *diffusion* of the light of the telescopic image in the translucent film of sensitive emulsion, and consequent diffusion or spreading of the image on the negative.

75. Can we determine in advance to what extent we can overcome, by means of the new refinements of guiding, focusing, refocusing, occulting, etc., that great discrepancy of 1 to 100 between the area of the diffraction disks and the area of the best photographs of them? This is one of the many questions which have been investigated with great exactness and with extreme interest in my astronomical laboratory, with the horizontal, electrically-operated practice-machine. There I have been able to duplicate innumerable

[4]This JOURNAL, November 1928, p. 365.

conditions which I had formerly studied and recorded minutely for this precise purpose and for similar ones, during ten years' experience in celestial photography with the greatest telescopes.[5]

76. These are the results: First, the effect of *diffusion* is negligible in the case of extremely faint stars, because their light does not penetrate, perceptibly, the film of sensitive emulsion. Second, in the case of brighter stars the effect of diffusion in enlarging the image on the negative varies approximately as the degree of *coarseness* of granulation of the emulsion, and also as the *thickness* of the film of emulsion. Third, in photographing *extremely faint* artificial stars with the practice-machine, duplicating actual sky-conditions with great exactness, and using *every refinement* of guiding, occulting, focusing, etc., now developed, I have eliminated *all* of that discrepancy of 1 to 100 between the areas of the diffraction disks and the areas of the photographs of them. Fourth, also in the case of *moderately* faint stars photographed with the practice-machine as just described, but with photographic plates having extremely fine *granulation* and extreme *thinness* of the film of emulsion, I have eliminated *all* of that discrepancy of 1 to 100.

77. By the combination of all of the Benecke methods which we have been able to develop thus far in my private laboratory we have now secured emulsions the sensitiveness of which is ten per cent. greater than that of commercial *Seed 23* emulsions, and the granulation of which, simultaneously, is *twelve* times finer than that of commercial *Seed 23* emulsions. It is certain that this result, as regards both sensitiveness and granulation, is only preliminary. The degree of *thinness* of the film or coat of a given emulsion which can be used with good results in *all* respects, is determined in large part by the fineness of granulation of that emulsion. With the new emulsions just described we have coated glass plates having accurate, concave surfaces, with a film of emulsion between nine and ten times *thinner* than that of commercial *Seed 23* plates. By using these plates in the practice-machine we have proved that not only *extremely* faint stars, but also *moderately* faint stars, can be photographed without preceptible spreading of their images due to diffusion. Negatives made with these plates permit $12 \times 12 = 144$ diameters magnification or enlargement without objectionable granulation becoming visible.

[5]This JOURNAL, November 1928, pp. 363-367.

PLATE XI

Spiral Nebula *on edge*, (H. H. 240 *Pegasi*) and field of very small spirals. Photographed by G. W. Ritchey with 60-inch Mt. Wilson Reflector, September 27, 1916.

The chain of small spirals begins at the bright oval nebula at the right-hand edge of the plate (about 1½ in. from bottom), and extends toward the *upper left*, through and beyond the large nebula; above and to the right of the bright star at the left edge (2¼ in. from top) the chain curves to the right and extends horizontally to a point vertically above the large nebula, where it again curves to the upper left and ends at the bright spiral near the upper edge of the plate!

PLATE XII

Spiral Nebula H. I. 53 *Pegasi* and small spirals. Photographed by G. W. Ritchey with 60-inch Mt. Wilson Reflector, August 28, 1916.

PLATE XIII

Group of Small Spiral Nebulae in *Pegasus*. Photographed by G. W. Ritchey with 60-inch Mt. Wilson Reflector. August 26, 27, 1916.

PLATE XIV

Spiral Nebula Messier 81 *Ursae Majoris*. Photographed by G. W. Ritchey with 60-inch Mt. Wilson Reflector, March 21, 1917.

78. An element of uncertainty as to the highest attainable accuracy of measurement of astronomical photographs has always existed in the past, due to the necessity of *wetting* photographic plates while developing, fixing and washing them. During this process the sensitive film of emulsion softens and swells to several times its thickness when dry. Do the photographed star-images return *precisely* to their original position, as the wet, thick, soft film of emulsion dries? To eliminate completely this element of uncertainty we have perfected in my laboratory an entirely successful method of developing, fixing and washing astronomical negatives in *dry gases* instead of in liquids. This process is greatly expedited by the extreme thinness of the new films of sensitive emulsion.

79. In paragraphs 70 to 73 I have recounted briefly the methods by which we shall increase the light-intensity of *telescopic* star-images at least 100-fold, or five magnitudes. In paragraphs 73 to 78 I have recounted briefly the methods by which, *independently* of the above, we shall increase the intensity of *photographed* images of faint stars (the images on the negative), also 100-fold, or five magnitudes, and this with photographic emulsions only ten per cent. more sensitive than those of commercial *Seed 23* plates. The combination of these methods will enable us to photograph stars which are ten magnitudes fainter (10,000 times fainter) than the faintest stars (21.5 magnitude of the Harvard scale), which I photographed with the 60-inch reflector, using 50 inches aperture and *Seed 23* plates.[6] And this takes no account of the still further improvement of photographic emulsions by the Benecke methods, which will surely come; of the still larger telescope apertures (than 5 metres) made possible by the Saint Gobain low-expansion glass and the cellular construction of mirrors; of the still better locations for these greater telescopes, in lower latitudes, at still greater altitudes, and in still drier and milder climates; and of improvements of the multiple-lens pellicule for the special needs of astronomical photography.[7] All of these will inevitably be secured by continuation of the methods which have already proved effective and successful.

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[6]This JOURNAL, October, 1928, pp. 314, 315.

[7]H. Chrétien, *Comptes Rendus*, vol. 186, p. 139, January, 1928.

80. The lower half of Figure 1 shows, highly enlarged, a section of a commercial photographic plate as made to-day for portrait, landscape, and amateur photography (*not* for astronomical photo-

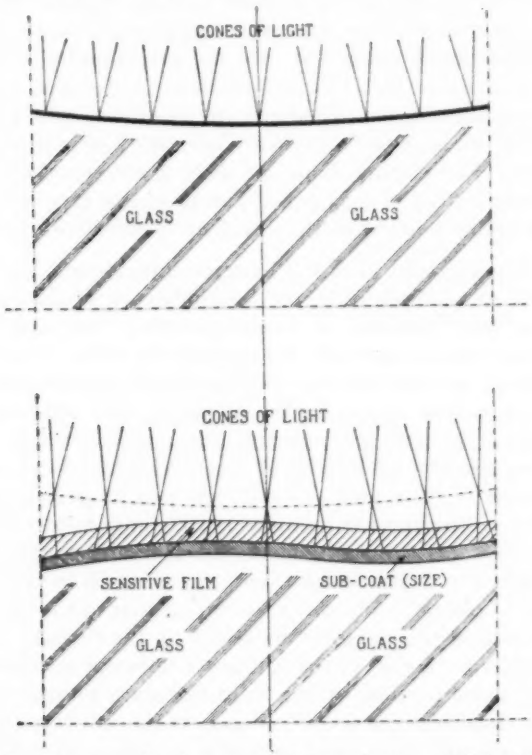

Fig. 1.—Diagram showing comparison of *commercial* photographic plate having irregular glass surface and *thick* film of emulsion (below), and *special* photographic plate having accurate glass surface and *thin* film of emulsion (above).

graphy), but as generally *used* to-day for astronomical photography. The true concave telescopic field is indicated by the curved, dotted line above the sensitive emulsion—the cones of light all focusing at this true concave field. The irregular glass surface which carries

the emulsion is indicated by the lower, irregularly-curved, solid line. The thick film of emulsion, the enormous loss of surface-intensity of the telescopic images due to inefficient focusing and refocusing, and the cone-effect due to thickness of the sensitive film are also indicated approximately to scale. The upper half of the drawing shows, on the *same* scale, a section of the new photographic plate made specially for astronomical photography, with its extremely thin film of fine-grained emulsion coated on an accurately ground and polished glass surface which coincides, within 0.0001 in., with the true telescopic field. This is one of a hundred equally obvious improvements which are almost totally neglected to-day in astronomical photography. The simpler and rougher kinds of celestial photographs are so comparatively easy to make—so *vast* and *new* and *rich* are the fields of exploration which have been revealed even by comparatively *crude* photographic telescopes and methods of operation, that to a very great extent the real possibilities and technical refinements of celestial photography have been, thus far, practically *untouched* and even lost sight of.

81. Professor Barnard frequently told me of his early work of comet-seeking, and of the great pleasure he had in studying the heavens with the low power and very large field given by his 5-in. refractor used as a comet-seeker. He said many times: "That, for me, was not labour; it was the greatest happiness; it was one of the greatest joys of my life." Later his superb photographs of the Milky Way, nebulae, comets, etc., enabled him to *extend* that happiness to many thousands of men and women all over the world. No type of reflector now known can cover such large fields of stars as Professor Barnard and others have photographed with suitable combinations of lenses. It is probable that the faintest stars shown in Professor Barnard's long-exposure photographs made with the 10-in. Bruce doublet are at least as faint as those which are at the visual limit of the 40-in. Yerkes refractor, namely, 16.5 magnitude of the Harvard scale.[8] It is important to note that the 5-metre Schwarzchild reflector which we are now considering will enable us to photograph with extreme sharpness fields 2°.5 in diameter, and to record stars which are not less than fifteen magnitudes, or one million times, fainter than those of 16.5

[8] E. C. Pickering, *Astr. Nach.*, 1905, No. 4026.

magnitude of the Harvard scale. In order that we may comprehend better the meaning of these figures, let us note the following series:

82. (*a*) At the best observatory sites now known stars as faint as 6.5 magnitude are easily seen with unaided eyes.

(*b*) At ordinary sites, stars 100 times fainter than 6.5 magnitude, or 11.5 magnitude stars, are easily seen with a good visual telescope of 4-in. aperture.

(*c*) To detect *visually* stars 100 times fainter still, or of 16.5 magnitude, we must have a telescope with about ten times the aperture of the 4-in.—a 40-in. aperture.

(*d*) To detect *visually* stars 100 times fainter still, or of 21.5 magnitude, we must have a telescope of about 400 in. (33⅓ ft.) aperture, and if it be a *refractor* its objective must have no greater absorption per unit of area than that of the 40-in. objective—conditions which, in the case of refractors, are impossible by any means now conceivable. But in 1910, by means of *photography*, using only 50 inches aperture of the 60-in. reflector, and using photographic emulsions of only moderate sensitiveness (*Seed 23*), I was able to photograph these 21.5 magnitude stars.[9] We note again that this result was obtained, *not* by a very great aperture, but by *direct photography*, and by the use of the moderate refinements of mechanical, optical and photographic technique which I had developed up to that time.

(*e*) Let us now consider stars 100 times fainter still—those of 26.5 magnitude. In September, 1910, after the success of the 60-in. Mt. Wilson reflector in photographing very faint stars and nebulae had been demonstrated, I expected and planned, with Mr. Hooker's urgent approval, to make the 100-in. Hooker reflector an important member of the *progression* of better and larger photographic telescopes, the possibility of which I *foresaw clearly* at that time. This possibility had been emphasized by the invention, in that year, of the Ritchey-Chrétien aplanatic combination of telescope mirrors[10], of the compact, economical type of equatorial mounting made possible by these mirrors,[11] and of the light,

[9]This JOURNAL, October, 1928, pp. 314, 315.

[10]This JOURNAL, July-August, 1928, pp. 212-230.

[11]This JOURNAL, October, 1928, pp. 304-310.

ventilated, cellular construction of optical mirrors.[12] These inventions permit the use of unprecedented refinements in the construction, permanence of adjustments, and operation of *equatorial* photographic telescopes.[13] Mr. Hooker generously offered to make these plans still more effective by adding to my private laboratory a generously-supported emulsion-laboratory for perfecting special photographic *emulsions* and *plates* for the special needs of astronomical photography.[14] If Mr. Hooker had lived the 101-in. reflector would have been constructed and used in accordance with these new inventions. With the greater refinements of construction and of operation thus permitted, together with an aperture twice as large as that of 50 inches used in making the 60-in. reflector photographs, and with special photographic emulsions coated on curved, polished, accurate glass surfaces, the *next* step of this series, namely, the photography of stars of 26.5 magnitude, would have been accomplished easily with the 101-in. Hooker reflector, even with the Ritchey-Chrétien focal ratio of 6.4 or 6.8 to 1.

We note that to detect *visually* these 26.5 magnitude stars would require an aperture of about 4,000 inches, or $333\frac{1}{3}$ feet. It is evident that by no methods known at present could an efficient *refractor* of this aperture be made. It is equally clear that only by means of the built-up, cellular construction of optical mirrors, together with the use of a *fixed* type of *reflecting* telescope, could we *attain* and *efficiently use* such an aperture as this. Let us note again that the construction of cellular disks consists chiefly in *building them up*, part by part, from *any desired number* of comparatively *small*, *selected* units of low-expansion vitreous material (nevertheless by *wholesale* methods as accurate as the finest optical work), by the repetition, again and again, of practically the same processes—just as bridges and buildings are constructed of many *selected*, *tested* units of steel and stone. Precisely the same principles apply to the *edifice*—the *mounting*, of the Fixed Universal telescope; it is a *massive building*, constructed of reinforced concrete, iron, steel and bronze. No part of it demands methods of construction greatly different from those used for the largest and

[12]This JOURNAL, November, 1928, pp. 374-376.
[13]This JOURNAL, October, 1928, p. 318.
[14]This JOURNAL, October, 1928, p. 320.

finest machinery and buildings constructed to-day. No better illustration of the unique possibilities of these improved methods of telescope construction could be given.

(*f*) The 31.5 magnitude stars which will be photographed with the 5-metre Schwarzschild reflector, with focal ratio, refinements, site, photographic plates, etc., as specified in the preceding paragraphs, are 100 times fainter than the 26.5 magnitude stars which we have just considered. It is not necessary to continue fully this comparison, to the 40,000-in. (3,333⅓ foot), visual objective (which must have no greater absorption per unit of area than the 40-in. one), with which, if it could be well made and well used, we would *just* detect, *visually*, these 31.5 magnitude stars. My purpose is to illustrate, in order to emphasize again, the hitherto unimagined powers of *celestial photography* with the new types of reflecting telescope, even with photographic emulsions only slightly more sensitive than *Seed 23* emulsions, with an aperture slightly less than *double* that of the 101-in. Hooker mirror which I have already figured, and with the reasonable and obvious refinements already developed and demonstrated in my laboratory. These refinements are demonstrated to be incomparably more effective for our needs, as well as incomparably more economical in cost than is mere bigness.

83. We have considered the results which we shall secure in photographing extremely *faint stars* with the 5-metre Schwarzschild telescope of 45.1 feet focal length. Let us now consider briefly what this same telescope will do in photographing *faint nebulae*, as compared with the results which I secured in this work with the 60-in. reflector with 50 inches aperture and with commercial *Seed 23* plates.

84. We note, first, that the *scale* of the new photographs will be 1.8 times greater in linear measure than that of the old. Second, taking account of (*a*), the comparative focal ratios of the two telescopes, (*b*) the two additional reflections in the larger instrument, (*c*) the loss by reflection and absorption at the thin, convex photographic plate, and (*d*) the greater transparency for blue-violet light at the site of the larger instrument (using the same factor for this as before, namely, 100/60), we find the surface-intensity of the telescopic images of celestial objects having ex-

tended surfaces, such as the nebulae, to be about 6.1 times greater in the larger telescope. Taking now the sensitiveness of the new emulsions as stated in paragraph 77, namely, ten per cent. higher than that of the *Seed 23* emulsions used with the 60-in. reflector, we find that with the larger telescope and the new emulsions the exposure-time required to secure equal intensity or density of the photographic image of a given nebula will be approximately one-sixth as long as before. The twelve-hour exposures which I sometimes gave with the 60-in. reflector will now be decreased to less than two hours.

85. Let us compare now the degrees of *fineness of detail* of celestial objects having extended surfaces (nebulae, planets and their satellites, the moon, etc.) which can be photographed with the old conditions and with the new. We note first that with the 50-in. aperture of the 60-in. reflector the resolving power for blue-violet light, for extended surfaces, corresponds to a magnifying power of 3,560 diameters,[15] but that in my work with that telescope the *actual* total magnifying power was limited to about one-tenth of 3,560 diameters, or, let us say, to 360 diameters, at the maximum, when commercial *Seed 23* plates were used, and to about 600 diameters when commercial *Seed Process* plates were used. The latter plates are too slow, and give too great contrast, for use in photographing any except very bright nebulae.

86. At this point, for the sake of clearness, and even at slight loss of continuity of the argument, I give the following elementary explanation, which relates to the very foundation of celestial photography:

A negative of the moon, for example, taken at the 45.1-ft. (541.35-in.) focus of the 5-metre telescope, measures about 4.75 inches in diameter. When this negative is viewed without any magnifying glass, at the distance of normal distinct vision (for which we adopt the usual conventional distance, 10 inches), it already represents a magnification of 54.135 diameters (541.35 inches ÷ 10 inches), due to the focal length, alone, of the telescope. If this negative could have been made on a photographic plate having sufficiently *fine* granulation and a sufficiently *thin* film or coat of sensitive emulsion, and with all conditions of atmospheric

[15] This JOURNAL, January, 1929, paragraph 22.

definition, focus, alignment, etc., sufficiently good to permit the full resolving power of this telescope to be utilized, this negative would permit enlargement or magnification of 260.44 diameters, that is, to about *103 feet* diameter; and when thus enlarged the *finest details* of it, when viewed at the distance of distinct vision, 10 inches, without further magnification, would be just at the limit of smallness or fineness which would permit their *general form* (for example, whether they were circular or rectangular), to be detected by the normal human eye. The *total* magnification, $54.135 \times 260.44 = 14{,}100$, corresponds to the photographic limit of magnifying power for extended surfaces, due to this aperture.[16]

87. The best *very sensitive* commercial emulsions almost universally used in astronomical photography at present have such coarse granulation that they permit magnification—*not* of the 260.44 diameters needed here, but of only two to four diameters, beyond which their granulation becomes objectionable to the eye, and, of course, destructive to all of the *fine* details of the telescopic image, which are entirely lost in its coarse structure. This may be likened to an effort to reproduce extremely fine details of a picture by means of a very coarse half-tone process or a very coarse stippling method. My best Mt. Wilson negatives, made on moderately sensitive *Seed 23* plates, permit a maximum magnification of 12 diameters (when they have been lightly developed) without objectionable granulation becoming visible; since the focal length of the 60-in. reflector is 300 inches, this corresponds to a total magnification of 360 diameters (paragraph 85).

88. With the 5-metre telescope, used on good nights at the best observatory sites now known, nothing except the granulation of the photographic emulsions will stand between us and the realization of the full theoretical magnifying power due to this aperture, namely, 14,100 diameters. Since the granulation of the new, special Benecke emulsions, as attained up to the present time, is twelve times finer than that of the best commercial *Seed 23* emulsions formerly used, we find that the total magnifying power permitted by the larger telescope in combination with the new emulsions is $54.135 \times 12 \times 12 = 7{,}795$ diameters. Let us call this, in round numbers, 7,800 diameters. Thus the *gain* in *smallness* of

[16]Paragraph 23 of the January article.

detail which will be recorded in the new photographs is *21.67 times* (in linear dimensions). In order to utilize the full photographic resolving power of this telescope, corresponding to 14,100 diameters magnification, we must increase the fineness of granulation of these emulsions 1.81 times farther still. There is no question that by concentrating on this point exclusively, this result can be attained without decrease of sensitiveness, within two or three years. When this is done the *gain* in smallness of detail which will be photographed with this 5-metre telescope will be *39.2 times*.

89. In order to appreciate the value of the results just considered, let us notice one important application of them: namely, the photographic study of the very small, very faint spiral nebulae. Basing my estimate upon the revelations in this respect of my long-exposure photographs taken with the 60-in. reflector, it is altogether probable that hundreds of millions of very small, faint spirals will be recorded, and their spiral character *distinctly shown*, by the larger telescope in combination with the better emulsions. They will be photographed in fields 2° or 2°.5 in diameter; in some parts of the sky thousands of them will be recorded on one negative. We shall be able to *classify* great numbers of them. We shall be able to determine the *inclination* of the planes of hundreds of thousands of them. We shall determine with great exactness their apparent *distribution* with reference to our galactic plane. We shall be able to estimate their relative *distances* by means of the relative sizes and *albedos* of great numbers of them.

90. In a small field around the spiral nebula H. II, 240 (N.G.C. 7814) *Pegasi* which I photographed with the 60-in. reflector September 27, 1916, with a long exposure, about thirty very small spirals are shown (Plate XI). About twenty of these small spirals apparently form a most remarkable curved *chain*. The smallest of these whose form and degree of brightness indicate clearly that they are *spirals* are about 5″.5 in length, corresponding to 0.2 mm., or 0.008 in., on the original negative. The great Andromeda Nebula, Messier 31, is at least 2° or 7200″ in angular diameter, or *apparently* more than 1,300 times larger than these very small spirals. On a brilliant glass positive enlarged 12-fold from the original negative, these smallest spirals are 0.096 inch in length. Together with the larger one (H. II, 240), which is 6′.0 in length,

and which is seen almost exactly on edge, they form a most impressive picture—even more impressive, if that be possible, than such *great* spirals as Messier 33 and Messier 31. For these very small spirals give the impression of stupendous distance—that they lie in unimaginable depths of space, that they appear *small* only because they are *far*, and that they may indeed be, on an average, more than a thousand times farther distant than the Great Andromeda Nebula. With the 5-metre telescope and the new emulsions the *scale* of the original negatives will be only 1.8 times greater (paragraph 84) so that these very small spirals which are 5″.5 in length will now be 0.0144 inch long on the negative. But *these* negatives will permit 260.44 diameters enlargement, instead of 12 diameters, so that our *new* glass positive will show these same small spirals 3.75 inches long, and with proportional increase of fine detail. We shall thus advance, by long, *sure* steps, toward the solution of some of the greatest problems of the physical universe.

91. Another illustration is as follows: Let us turn to the preceding article of this series (January, 1929) and to Plate VIII of the large spiral Messier 51. An unusual feature of this spiral is the great, *non-spiral*, nebulous mass near the bottom of the plate, in which one of the two main branches of the spiral terminates. This appendage, in itself, is not of unusual structure; but it is difficult to understand why a mass having this structure should be physically connected to a strongly-marked spiral. Our difficulty is due in part to the fact that only a few of the spirals—perhaps thirty or forty in all, are large enough, or *near* enough, to enable us to photograph with the best existing telescopes the details of their structure with great distinctness. Therefore we cannot as yet, by means of effective *classification* of *great numbers* of them, gain an insight into the life-history of any given spiral. With the modern photographic telescope and the new celestial photography we shall photograph tens of thousands of spirals, instead of thirty or forty, on a scale sufficiently great for highly-effective study and classification. We shall thus advance, by *another* long, *sure* step toward the solution of that ultimate physical problem, the structure and evolution of the universe.

92. It is interesting to note another important point concerning the study of nebulae: The vast majority of those which have been

photographed are too faint to be studied, measured or even detected, *visually*, with any telescope. On the other hand it is certain that never yet has any nebula been *photographed* with sufficiently fine-grained plates and with sufficient refinement of technique to reveal the nature of the *small* details of its structure which are well within the theoretical resolving power of the telescope used. In other words, we cannot study the small details of faint nebulae *visually*, because these details are too faint and too lacking in contrast to be detected by the human eye with any telescope; and we have never *photographed* these small details because of the too coarse granulation of the commercial emulsions used. My Mt. Wilson photographs of the annular nebula Messier 57 *Lyrae* taken on *Seed Process* plates, and those of the filamentous nebulae N.G.C. 6960 and 6995 *Cygni*,[17] give a slight indication of the marvellous nebular structure which we shall photograph when the telescope here considered becomes available in combination with the special emulsions. We recognize again the wisdom and foresight of Mr. Hooker, who in 1910 wished me to develop these special emulsions in my private laboratory, with his generous financial support, and in time to be available for use with the Hooker reflector. After all arrangements and engagements for this work had been far advanced, insurmountable obstacles, other than technical and financial ones, compelled Mr. Hooker to postpone it. A great field of profoundly important research on the nebulae *awaits* us here, a field which is to this day almost entirely untouched.

93. The spiral nebula H. I, 53 *Pegasi* (Plate XII), was photographed by the author with the 60-in. reflector with a long exposure and with *Seed 23* plates on August 28, 1918. This spiral is markedly of the type of the Great Andromeda Nebula, and like the latter, it has a number of smaller spirals apparently so near to it and so numerous as to give the impression of close physical relationship. The large spiral measures ten minutes of arc in length on the original negative, while the largest of the four small ones at the right of it measures one minute of arc in length. We note the remarkable details of the dark rifts at the left of the centre of the large spiral. There can be no question that these rifts are identical

[17]Plates V, VI of the January article.

in nature with the complicated dark rifts photographed near the central parts of the Great Andromeda Nebula and of Messier 81 (Plate XIV).

94. The Great Andromeda Nebula measures about 2° in apparent length, or twelve times larger than H. I, 53. Since the 5-metre Schwarzschild combination of the Fixed Universal telescope with the special emulsions will photograph details 39.2 times smaller than the smallest details which I have photographed with the 60-in. reflector with *Seed 23* plates (paragraph 88), we shall photograph H. I, 53, with the 5-metre telescope on an *effective* scale 3.27 times greater than that of the Great Andromeda Nebula as photographed with the 60-in. reflector. In the next paper of this series we shall see a highly-enlarged 60-in. reflector photograph of the central parts of the Great Andromeda Nebula, in which the spiral structure is seen to extend in to the small central nucleus, and in which innumerable fine details of the great dark rifts are shown. It is interesting to note also that with the 5-metre telescope we shall photograph the largest one of the four small spirals at the right of H. I, 53, on an *effective* scale four times greater than that of H. I, 53, itself as photographed with the 60-in. reflector.

95. Probably no question relating to the new astronomy and to cosmogony is of greater interest and importance than the question of the nature of the small spirals—whether they are indeed other stellar systems of the same order of dimensions as our Milky Way. One prominent American astronomer has said recently that this is a question which can be determined only by future generations of astronomers. But with the 5-metre Fixed Universal telescope and the new emulsions we shall *answer* that question, stupendous as it is, and scores of similar ones, in a few *years* instead of in a few *generations*.

96. Plate XIII shows a most remarkable group of small spirals in Pegasus, which I discovered with the 60-in. reflector at the edge of a large-field photograph of H. I, 53. The upper three spirals, at least, of this group apparently form a closely-related physical system. This is indicated by the abnormal forms of their spiral branches, which are apparently greatly distorted and even torn asunder by mutual attraction. The member of the group which is most normal in form—the largest and lowest one, is about two

minutes of arc in length; when photographed with the 5-metre Fixed Universal telescope it will have an *effective* scale two-thirds as great as that of the Great Andromeda Nebula as photographed with the 60-in. reflector. The magnificent spiral Messier 81 measures 15′ in length, or about 7.5 times larger than the largest spiral of this group. Thus we see that the 5-metre Fixed Universal telescope will photograph this group of spirals on an *effective* scale about five times greater than that of Messier 81 as photographed with the 60-in. reflector. If we now note the exquisite detail shown in Messier 81 we can have some conception of the profoundly interesting and important details of structure which will be revealed especially in the upper three members of this group, due to the effects of mutual attraction, as indicated in the photograph. It is not improbable that comparatively rapid changes of form will be detected in this group, due to the stupendous gravitational forces which are apparently in action here at close range.

97. Plate XIV is from a negative of Messier 81 *Ursae Majoris* made by the author with the 60-in. reflector, March 21, 1917. A three-night exposure was intended, and exquisite atmospheric definition continued for about three hours on the first night. Conditions were so bad on the following nights that additional exposure was not given. Among all of my photographs of spiral nebulae only one, the best one of the Great Andromeda Nebula, shows equally fine details. This spiral is strikingly similar in its general characteristics to the Great Andromeda Nebula. The large, bright region consists of apparently amorphous luminosity, with complicated dark rifts which are generally of marked spiral form. An unusual system of nearly straight dark rifts which cross each other at an acute angle is seen just below the very bright centre. These details are strongly shown on another negative of this spiral taken on February 6, 1910, with a longer exposure but with inferior air-conditions. This system of intersecting straight rifts resembles in a most marked manner a system of intersecting, straight dark rifts which Professor Barnard has photographed in the Milky Way near the northern edge of his "Region of *58 Ophiuchi*." This region is shown in Plate 23 of Professor Barnard's recently-published "Photographic Atlas of Selected Regions of the Milky Way." In the photographs of larger spiral nebulae which accompany the

succeeding article of this series I shall show that far more marked resemblances than this exist between the dark rifts in great spiral nebulae and the dark rifts which Professor Barnard has photographed in the Milky Way near *Theta* and *Rho Ophiuchi*.

98. In the opinion of many French astronomers who have compared these photographs, and in my own opinion, these strong resemblances, which are shown *graphically*, by means of *direct photography*, indicate that a region of the Milky Way in the constellation *Ophiuchus* is near the physical centre of our galactic system.

99. Let us now make the following three assumptions: (*a*) That the distance from us of the physical centre of the Milky Way (in *Sagittarius* or in *Ophiuchus*) is of the order of 45,000 light-years, as recently estimated by Shapley; (*b*) that the distance of the Great Andromeda nebula is of the order of 1,000,000 light-years, which was indicated in 1917 and 1918 by my discovery and study of a large number of very faint novae near its centre, and which was indicated several years later by Hubble's discovery and study of Cepheid variables in it; and (*c*) that the spiral Messier 81 *Ursae Majoris* (the angular diameter of which is about 15′) is really of about the same *actual* dimensions as the Great Andromeda Nebula, the angular diameter of which is about 2°, so that the distance of Messier 81 is of the order of 8,000,000 light-years.

100. On the basis of the above assumptions the Great Andromeda Nebula is of the order of 22 times farther distant from us, and Messier 81 is of the order of 178 times farther distant from us than is the physical centre of the Milky Way. But Professor Barnard has easily photographed myriads of individual stars of the Milky Way in *Sagittarius* and *Ophiuchus* with the 10-in. Bruce lens of Yerkes Observatory and with the 6-in. Willard lens of Lick Observatory. Since the 5-metre Fixed Universal telescope will photograph faint stars which are fifteen magnitudes or 1,000,000 times fainter, and therefore which are, on an average, 1,000 times farther from us than the individual stars of the Milky Way shown in Professor Barnard's photographs (paragraph 81 above), it is altogether probable that we shall easily photograph with the 5-metre Fixed Universal telescope the myriads of individual stars which constitute that "large central region of apparently amorphous luminosity" of Messier 81.

101. In this photograph of Messier 81 exquisitely fine details of the spiral branches are shown. We note again the presence of *nebulous stars* in the convolutions. These are larger, softer, usually less bright and less perfectly round than the superposed *real* stars of our own galaxy which are easily recognized by comparison. On a glass positive which is enlarged 12 diameters from the original negative of this spiral, many of these hazy, nebulous stars measure from one to two millimetres in diameter. Photographs of this spiral taken with the 5-metre Fixed Universal telescope will permit *effective* enlargment 39.2 times greater than that of the present enlarged positive, so that these same nebulous stars will be shown from 40 to 80 mm. (that is, from 1.6 to 3.2 in.) in diameter, and with *proportionally finer detail.* If those nebulous stars shall thus prove to be the globular star-clusters of that *other* galaxy, corresponding to the magnificent globular star-clusters of our Milky Way (Plate IX, October, 1928) we shall be able to count thousands of individual stars in each of the larger of *those nebulous stars.* And we shall thus learn also the nature of those apparently strongly nebulous *aggregations* of nebulous stars which are shown by long-exposure photographs to be present in large numbers in the spiral branches of the great majority of the larger spiral nebulae, but which have *no known counterpart* in our own galaxy. (See the descriptions of Plates in the January article.)

102. In ways suggested in the foregoing descriptions of Plates XI, XII, XIII and XIV, and in many other ways, we shall endeavour to answer that great question as to the *nature* of the hundreds of millions of spiral nebulae which will be revealed by the use of the 5-metre Fixed Universal telescope in combination with the special emulsions. For the solution of that stupendous problem we shall develop still finer-grained and more sensitive emulsions, and we shall construct still larger Fixed Universal telescopes such as the 8-metre one which will be illustrated in the next article of this series.

Will those millions of spiral nebulae prove to be other galaxies similar to our own, the Milky Way? The importance of this conception and of its *complete demonstration;* the profound influence which such a demonstration must exert upon the thought of the entire world and of all future generations; the possibility of making

this demonstration a *graphical, visual* one, by means of actual photographs which can be seen and understood by all students and by millions of interested men and women everywhere—*these* are some of the grounds upon which we shall secure *generous* support for the modern photographic super-telescopes and for the new celestial photography.

Observatory of Paris,
January 3, 1929.

REVIEW OF PUBLICATIONS

Discovery of the Earth by George Parson. 232 pages. 5¼ x 8 inches. Boston: J. W. Luce & Co., 1929.

This well-printed and tastefully-bound volume discusses in a simple way the ever-interesting subject of the evolution of the solar system.

The first half of the book gives a review of the principal cosmogonies proposed from Kepler's time to the present. The author shows a wide acquaintance with the literature of the subject and analyses the various theories in an appreciative yet critical manner. No two readers would agree as to the relative importance to be attached to these hypotheses and may not agree always with the author, but he gives his reasons for his views and his language is in excellent literary form. Indeed it is a real pleasure to read the book.

The author states (p. 158) that he aims to set forth a new conception of the earth's place in the physical universe, and to help to popularize the twin studies of astronomy and cosmogony. According to his view Mercury, Venus, the earth, the moon and Mars are solar satellites and owe their origin to the gradual condensation of the central body; while the great planets—Jupiter, Saturn, Uranus and Neptune—were formed from the disc of nebulous matter which surrounded the ancestral sun (p. 165). The author contrasts the inner planets and the outer planets and thinks they differ so widely that it is reasonable to suppose that they were produced in two entirely different ways. The "discovery" is that the earth is a satellite to the sun just as Ganymede is a satellite to Jupiter.

The book closes with a three-page list of books referred to in the text, and a good index.

C. A. C.

NEWS AND COMMENTS

Professor Frank Schlesinger, Director of Yale University Observatory, was presented at a special meeting on April 12 with the Bruce medal of the Astronomical Society of the Pacific for his work in photographic parallaxes and in other branches of astronomy.

Professor E. A. Milne of the University of Oxford will give at the summer session of the University of Michigan a course of lectures on "The Physics of the Stars".

Professor A. Vibert Douglas of McGill University, addressed the Ottawa Centre, Royal Astronomical Society of Canada at the National Museum on March 22. Miss Douglas gave a most interesting talk on "The Signs of the Zodiac".

Professor George Struve of the Department of Astronomy, University of Berlin, will be a member of the Faculty of the University of Chicago for the coming summer quarter.

Through the courtesy of the Director of the Dominion Observatory, the Ottawa Centre of the Royal Astronomical Society of Canada held a well-attended Soirée on April 12 at the observatory. In addition to the regular display of the instruments and specimens of work of the various branches of the observatory, Dr. Ami exhibited a splendid collection of stone implements and art of prehistoric man. As Director of the Canadian School of Pre-History in France, Dr. Ami has made some wonderful collections and discoveries. His vast fund of interesting information given in his inimitable enthusiastic way, was greatly appreciated by the visitors.

Mr. Frank S. Hogg, who on graduating at the University of Toronto in 1926 won the Royal Astronomical Society of Canada's Gold Medal and who since then has been continuing his studies at the Harvard Observatory, has been awarded a Sheldon Travelling Fellowship. He will probably spend the year in Europe. Mr. Hogg's home is in Preston, Ont.

It is with deep regret we record the sudden death on April 6 of Dr. E. T. White, the secretary of the London Centre, and a member of the General Council of the Society. Dr. White was Mathematical Master of the London Normal School. A further account of his life will be given in the next issue. REDeL.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

The Movements of Venus

Mr. Thos. Waddell of Brechin, Ont., asks for a sketch of the movements of Venus during the last two months.

The orbit of Venus is almost circular and its radius is 7-10 of the earth's mean distance from the sun. Let us represent the orbit of Venus by a circle having a radius of 7 inches and take a point 10 inches from the centre to represent the earth's position. Of course the earth is moving in its orbit, but for our present purpose we need not consider that.

First let Venus be in that part of its orbit farthest from the earth, that is, earth, sun and planet are in line with the sun between. In this configuration Venus is said to be in superior conjunction with the sun. It was so on July 1, 1928. Venus now moves to the left, as seen from the earth, and the angle between the lines from the earth to the sun and the earth to the planet increases until it reaches a maximum value of about 48° (Feb. 7, 1929, see *Handbook*, pages 23, 30, 31). The angular separation (or *elongation*) of the planet from the sun now decreases until the planet comes between the sun and the earth. In this configuration the planet is said to be in inferior conjunction with the sun (April 20, 1929). The planet moves to the high hand—or west—of the sun and becomes a morning star. Its elongation from the sun increases to a maximum (June 29), and then diminishes again until superior conjunction is reached (Feb. 6, 1930). A diagram illustrating the above is found in Russell, Dugan and Stewart's *Astronomy*, page 237.

The path which the planet appears to take amongst the stars is found on page 3 of the cover of the *Handbook*.

The Largest Meteorites

In a recent number of *Science News-Letter*, information was given about a 70-ton meteorite said to have been found at Otjihaene,

near the head of the Grootfontein railway in the northeastern part of Southwest Africa. It is imbedded in soft limestone and is 10 x 10 x 4 feet in size. It is the largest meteorite ever actually discovered, but there is evidence that other larger ones have fallen to the earth.

It is believed that the famous Meteor Crater in Arizona was caused by a meteorite many years ago. The great meteorite which fell in the Yenissei Province of Siberia on June 30, 1908, was also much larger; and another huge crater due to a meteorite which fell at some undetermined time has been discovered in the Pamir, in Central Asia, near Afghanistan. But the actual body has not been found in any of these three cases.

A New Ohio Observatory

A new observatory is promised for the Baldwin-Wallace College, Berea, Ohio. The site and $33,333 were presented by Benjamin C. Wood as a memorial to his mother, Mrs. Lavina Mastick Wood. Dr. O. L. Dustheimer expects to secure a 15-inch refractor for the observatory. Further details will be given later.

What was it?

Professor A. S. Eve, of McGill University, having obtained permission, sends two letters written by Rev. H. W. Parry, Maple Grove, Megantic Co., Que., regarding a phenomenon observed near Foster, Que., in the autumn of 1917. Extracts from these follow.

On this occasion, possibly around Oct. 31, 1917, I left the hall where a social was in progress about midnight, driving a quiet horse, in an open buggy. The night was clear, with slight haze in the low lying land, and it was evidently going to freeze. A few insignificant signs of Northern Lights flickered towards the north and west.

As I drove along the straight road, with the C.P.Ry. track to the right, and grass fields bordered by a maple grove 100 to 150 yards back from the roadway on the left, my horse began to show signs of alarm, as though a train were coming up behind, and on looking round to ascertain the cause, there was close behind me on my left, a whitish light, catching up to me, but between me and the background of dark trees. I reined in the horse with difficulty, and watched this display pass. I could distinctly see the forms of the trees through it. It seemed to be 70 or 80 yards in length, and flickering as Northern Lights do. It would vary in height from the ground twenty to sixty feet, and after passing me several hundred

feet, it gradually rose up into the air, and as its distance away increased, and its longitudinal view changed, it seemed to come together more column-shaped, and got brighter, soaring up into the air, spreading out, contracting again, changing colour, until it merged with many similar displays, and eventually was high up in the air indistinguishable from what I was before in the habit of considering just an ordinary little display of Northern Lights, fairly overhead, but towards north.

I have mentioned this to many people, but to no one who had any intelligent idea about such things. No doubt you can explain it. It was a revelation to me, seeing it pass plainly between me and the background of dark trees. It gave me rather a feeling of awe, as well as my horse. And then to see it gradually become a part of what I had always associated with the North Pole—just an ordinary little display of Northern Lights. It proved to me, I thought, that the displays which we see overhead, turning different colours, white, sea-green, ruby, and gold, often very, very wonderful and beautiful, are not Northern Lights at all, possibly electricity changing in form and colour according to currents of air of different density, or temperature, or motion, and not very far off, perhaps a quarter of a mile, perhaps a mile or two, perhaps more,—anyhow the stars shine through them.

. . . . .

I agree with you that the light which I saw was not Northern Lights, and from that evidence the brilliant and erratic overhead displays are not Northern Lights, for the light which caught up to me, and passed me, I watched until it rose in the air and joined with just such an overhead, but comparatively insignificant, display.

What I saw could not possibly have been mist or haze illuminated by the high up Northern Lights, because in the first place there were no Northern Lights of sufficient brilliance to light anything, and then the light passed me at a rapid rate and was distinctly visible between me and the background of trees.

The first thought which came on reading Mr. Parry's letters was that the illumination he had seen was due to the headlights of an automobile or a locomotive behind him, but these objects would apparently have made themselves heard soon afterwards. It may be remarked that strange slender auroral streamers sometimes appear to the south. On the evening of March 11 such were seen in Toronto at about 10.40. They stretched across the sky from the south-east horizon and passed about 30 or 35 degrees south of the zenith. Close observation of their motion suggested that they were auroral in nature, though nothing of the sort was seen in the north. However, half an hour later there were unmistakable auroral streamers in the north. Perhaps some reader may suggest an explanation of Mr. Parry's phenomenon.—C. A. C.

MEETINGS OF THE SOCIETY

AT MONTREAL

December 12, 1928—The third meeting of the Montreal Centre was held in the Mechanics Institute at 8.15 p.m., the President, Dr. A. H. MacCordick, in the Chair.

In the absence of the lecturer, who had been unavoidably called from town, the President delivered an impromptu address upon the heavens as they appear to the naked eye during the month of December. The evening being clear, the members afterwards went out of doors and observed the sky either with binoculars or unaided vision.

Col. W. E. Lyman and others took part in the informal discussion. The thanks of the Society are due to the President for so admirably meeting a very awkward emergency.

January 31, 1929—The fourth meeting of the Montreal Centre was held in the Macdonald Physics Laboratory at 8.15 p.m., the President in the Chair.

New members were elected as follows:—

Mme. LeBeuf	Dr. A. Bramley-Moore	Dr. S. Ortenberg
Mr. Brietckze	Dr. Jas. Forrest	Dr. A. B. Robillard
	Dr. H. E. MacDermot	

The President expressed, on behalf of the Society, the grateful thanks of all members to Dr. A. S. Eve, Director of the Macdonald Physics Laboratory, for his continued kindness in allowing the meetings of the Society to be held in this building.

"The Solar System and the Milky Way" was the subject of the lecture given by Dr. A. Vibert Douglas. Moving slides of the Solar System showed in a striking manner the movements of earth, moon, minor and major planets and comets, and the phenomena of seasons and tides. Extracts were read from the writings of Copernicus, Galileo, Horrox and Kant.

Following this, there was shown a series of slides made from Barnard's *Atlas of Selected Areas of the Milky Way*, and an account was given of the recent investigation by Dr. Shapley regarding the great density of stars in the neighbourhood of Sagittarius, the veil of obscuring nebulous matter between us and the nucleus of the galaxy and the spectroscopic evidence for the belief that stars in this region of the galaxy are subject to tremendous meteoric bombardment.

February 21—The fifth meeting of the Montreal Centre was held in the Macdonald Physics Laboratory at 8.15 p.m., the President in the chair.

The Secretary referred to the death of Mr. H. W. Jesmer, a member and councillor of the Society.

New members were elected as follows:—

Miss I. E. Brittain	Mr. O. A. Ferrier
Mr. R. B. Ross, Jr.	Mr. Duchart Chesney

Mr. E. E. Bridgen gave an interesting address entitled "The Constellations". His summary of his lecture follows.

The sky on a clear night presents a spectacle of absorbing interest, and arouses the desire to know something of the multitude of stars visible. Not that their number is infinite, as perhaps we might think from a casual glance, for only about six thousand stars are within the unaided vision, and as only one half of this number can be seen at any one time, and as visibility near the horizon is usually poor, due to haze and smoke, it is probable that even on the clearest night not more than two thousand stars can be seen.

When, and by whom the heavens were first mapped out is unknown to us, but the groups of stars, or constellations, which the ancient observers formed, using a wonderful imagination which peopled the sky with the figures of animals, heroes, mythical beings and inanimate objects, remain as an evidence of the antiquity of our study, and form a most convenient guide to the heavens.

Observations were made and recorded by many of the ancient peoples—the Chinese, Hindus, Chaldeans, Egyptians and Greeks, by the vanished races of Peru and Mexico. The Phoenicians owed their maritime power to their knowledge of navigation, which science was the direct offspring of astronomy.

Our earliest definite information regarding the constellations is from the *Almagest*, of Claudius Ptolemy, dating from about 150 A.D. This is but a revision of the list of Hipparchus, made about 140 B.C. and this list, some think, was based on that of Eudoxus, B.C. 370, who used astronomical knowledge at least 2000 years old in his time. Ptolemy's list gives 48 constellations, 21 northern, 15 southern and 12 zodiacal, but these do not cover the entire heavens. The zodiacal constellations constitute a circle of the heavens through which the sun moves, and the northern and southern groups are north and south of this circle respectively. From the figures used, from those parts of the heavens left unmapped, and from various ancient writings it appears probable that the people who mapped out the heavens lived in the Euphrates valley more than 3000 years B.C.

The number and arrangement of the constellations has not been constant, although from the time of Ptolemy until the year 1601 A.D. there was no change. In that year Tycho Brahe added two, and in the next two hundred years numerous changes were made, constellations being added and again dropped, until at the present time 88 are generally recognized, which have definite boundaries and which cover the entire heavens without overlapping. The importance of recognizing the outlines of the constellations and the principal stars in a study of the heavens is evident, for the constellations are in the heavens as the boundaries of states or countries on the surface of the earth.

The diurnal motion of the stars, of course, is not real but is due to the rotation of the earth.

If an observer faces the south, the stars will appear to rise in the east, pass across the sky, and set in the west, just as the sun and moon, but if he turns to

the north, he will notice that some of the stars do not go below the horizon, but seem to revolve about a centre, which is known as the north celestial pole. This pole is the point through which the earth's axis of rotation would pass, if projected. It is apparent that some parts of the heavens visible here are never seen in the southern hemisphere, and that some constellations never come above the horizon.

To illustrate the above statements slides were shown, and running comments made upon the relative positions of the various outstanding stars and star groups from season to season.

Mr. J. Luttrell moved a vote of thanks to the speaker. An animated discussion followed.

March 1—The sixth meeting of the Montreal Centre took place, by invitation of the McGill Chapter of the Society of Sigma Xi and the McGill Physical Society, in the Macdonald Physics Laboratory, at 8.15 p.m. The President of Sigma Xi, Dean H. M. Mackay, occupied the chair.

The lecturer was Dr. J. C. McLennan, F.R.S., of the University of Toronto, his subject being "The Relation of Light to Matter".

For an hour and a half the audience was held spellbound while the theories of Newton, Fresnel, Young, Maxwell, Rutherford, Bohr, Planck, Einstein and the leaders of the present school of wave mechanics were expounded. Models of atomic nuclei were shown and diagrams of the arrangement of the orbital electrons in various atoms, of the possible energy levels and metastable states. Special mention was made of cosmic radiation, of the auroral green line, of the nebular lines and, in conclusion, of the Raman effect.

In thanking the lecturer, Dr. Eve referred to him as the Conrad of light.

A. VIBERT DOUGLAS, *Secretary.*

AT TORONTO

February 26—The regular meeting was held at 8 p.m., Mr. J. R. Collins in the chair.

The lecture of the evening was by Prof. H. R. Kingston, of Western University, London, Ont., under the title of "The Wonderful Heavens". Before entering on his subject proper, the lecturer outlined the history of the London Centre of our Society of which Prof. Kingston is President. Splendid slides of the University buildings and grounds were shown, the Centre finds accommodation for its meetings in one of the University buildings. The subject was treated in a very interesting and instructive way, and a wealth of astronomical knowledge was imparted to an interested audience. Prof. Kingston had prepared the lecture as an example of his method of popularizing astronomy to the general public, and he is evidently much in demand as a public lecturer on the subject. Many good slides were shown. Dr. L. Gilchrist, Dr. R. K. Young and Mr. A. F. Miller addressed the meeting with expressions of appreciation and voiced the opinion that the London Centre was exceedingly fortunate in its choice of a President.

E. J. A. KENNEDY, *Secretary.*

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